ATMEAI: Developed jointly by AREVA and Mitsubishi

by Andreas Goebel

The ATMEAI reactor is an evolutionary 1,100-MWe pressurized water reactor designed by ATMEA, a joint venture of AREVA and Mitsubishi Heavy Industries Ltd. (MHI). The design process has drawn upon the 40-year worldwide PWR experience of AREVA and MHI, which have designed and built more than 130 reactors. Originally developed to meet stringent U.S. safety regulations, the ATMEAI reactor design has been reviewed and deemed compliant by safety authorities elsewhere, including in France and Canada. Preselected in Brazil, Argentina, and Viet-

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Digital aerial view of two ATMEAI reactor units

A cutaway view of the ATMEAI reactor and adjacent buildings
namin, and under consideration in proposed power plant projects in Kazakhstan and Turkey, the ATMEA1 reactor benefits from commercial prospects throughout the world. The ATMEA1 reactor features a 3,150-MWt nuclear steam supply system with three coolant loops. The primary system is composed of a reactor vessel that contains fuel assemblies, a pressurizer, and, in each of the three loops, one reactor coolant pump and one steam generator. Also in the primary system are all of the related control and protection systems. In each loop, the primary coolant leaving the reactor pressure vessel is directed to a steam generator, and then to a reactor coolant pump, before returning to the reactor pressure vessel. The pressurizer, connected to one of the three loops, keeps the primary pressure constant. The primary system design, configuration, and main components are similar to those of currently operating PWRs. In internal volume, however, the ATMEA1 reactor’s primary components are larger than those used in current three-loop units in order to support steady operation and increase safety margins.

The reactor core consists of 157 fuel assemblies, each with fuel rods arranged in a 17 × 17 square array, together with 24 control rod guide thimbles. The rods contain pellets of either slightly enriched uranium dioxide or mixed-oxide fuel. The contents of an ATMEA1 core can range from all uranium to as much as one-third MOX for the standard design, and up to 100 percent without any major design modifications. The length of the fuel cycle can be set from 12 to 24 months.

The ATMEA1 reactor pressure vessel includes improvements over the vessels of existing reactors. Bottom-mounted penetrations for in-core instrumentation have been eliminated, with instrumentation penetrating the ATMEA1 vessel from its top. The number of welds has been reduced and weld geometry has been improved so as to simplify the manufacturing process, nondestructive examination, and in-service inspection. Also, the vessel will be made of materials with features such as brittle fracture resistance.

The ATMEA1 steam generators are vertical, allowing steam to circulate naturally. Included are U-tube heat exchangers, as well as integral moisture separating equipment. An axial economizer increases steam pressure, leading to improved thermal efficiency. The tube material is alloy 690 TT, widely used in steam generators throughout the world, and highly resistant to primary stress corrosion. Compared to operating plants, the ATMEA1 steam generator’s secondary side has a larger water inventory, allowing more time to take action in case of a postulated total loss of secondary water.

Active safety

In the ATMEA1 reactor design, safety is achieved through powerful active systems, with passive systems called upon only for specific actions. There is an optimized balance between system diversity and redundancy, and severe accident management systems have been validated through a deterministic approach for beyond-design-basis situations, to ensure that the plant remains safe and under control at all times.

The reactor is designed to have a core damage frequency of less than 10⁻⁵/reactor-year, and a large release frequency of less than 10⁻⁶/reactor-year. The ATMEA1 reactor complies with U.S. regulations and industry consensus codes and standards; the International Commission on Radiological Protection’s recommendations; and International Atomic Energy Agency safety standards.

Incorporating the experience gained through the developments of AREVA’s EPR and MHI’s APWR reactors, the safety design of the ATMEA1 reactor is based primarily on deterministic analyses (which strictly apply the defense-in-depth concept), complemented by probabilistic analyses. This results in the following:

- Favorable plant transient behavior, because of large steam generator inventory and pressurizer steam volume.
- Simplification of the safety systems, and functional separation.
- Mitigation of common-mode failures through segregation and diverse backup safety functions.
- Low sensitivity to failures, including human errors, through incorporation of adequate design margins.
- Longer times for operators to take actions.

Continued
Less sensitivity to human errors, through optimized digital instrumentation and control systems.

A robust containment pressure vessel.

For all safety analysis, the long-term safe state is retained as safe shutdown state. Low-probability events with multiple failures and coincident occurrences, up to the total loss of safety-grade systems, are considered in addition to the deterministic design basis. A probabilistic approach is used to define these events, and both deterministic and probabilistic approaches are used to assess the specific measures available to manage the events. As a result, the probability of severe accidents has been greatly reduced in the ATMEA1 design, and innovative features have been implemented to design out early containment failure. In addition, design provisions have been adopted to further reduce the residual risk, to mitigate core melt, and to prevent large releases. The ATMEA1 reactor thus integrates top-level safety features to protect, cool, and confine the reactor in all situations, including extreme conditions.

**Protection**

An ATMEA1 plant—the reactor building, the safeguard building (including the plant control room), the fuel building, and the emergency power supply buildings—is, by design, protected against a wide range of external hazards, including the following:

- High-level seismic events, with a 0.3g safe shutdown earthquake level as a design standard, and appropriate design margins.
- External flooding, with leak-tight buildings housing safety systems as well as equipment.
- Explosions, missiles, tornadoes, and fire.

The ATMEA1 reactor is also designed to withstand the crash of a military or large commercial airplane, ensuring the prevention of any long-term impact on the environment, and upholding the structural integrity of the reactor building, safeguard building, emergency power sources buildings, and fuel building; the prevention of airplane fuel ingress into those same buildings, to prevent internal fires or explosions; safe shutdown capability; and long-term availability of emergency core cooling and residual heat removal systems.

**Cooling**

The strategy behind the ATMEA1 reactor calls for the use of robust, protected, and permanently installed equipment and resources to maintain or restore core cooling, containment cooling, and spent fuel cooling for a prolonged period of time in all reactor states. Cooling would be maintained during extreme external events, such as earthquakes and external flooding, beyond those events accounted for in the design basis.

The ATMEA1 design integrates three independent safety trains, which are fitted to each of the three reactor loops. These trains are protected against external hazards. An additional fourth train (Division X) is installed for cooling chain systems, providing both on-power maintenance capability and diversity. Division X can also be used during preventive or corrective maintenance activities on any other train.

Each of the three safety trains boasts the following components:

- **The safety injection system**—This system injects and recirculates emergency cooling water to maintain the reactor core's coolant inventory following a loss-of-coolant accident (LOCA). Advanced accumulators supply boric acid water during the blow-down phase and the reactor vessel refill phase at a high-injection flow rate, as well as at the core reflooding phase at a lower flow rate. The accumulator is a passive system that is self-activated and driven by pressurized gas, and therefore does not require any electrical triggering systems.

- **The containment spray system and the residual heat removal system**—These sys-
The reactor's redundant systems

- Prevention of high-pressure core melt through the use of decay heat removal systems, complemented by dedicated primary system overpressure protection.
- Discharge of the primary system into the containment in the event of a total loss of secondary-side cooling.
- Molten core spreading and cooling through the use of passive catalytic recombiners to reduce hydrogen concentration in the containment.
- Control of increases in containment pressure by a dedicated severe accident heat removal system, consisting of a spray system with recirculation through the cooling structure of the melt retention device.
- Collection of the output from all leaks, and prevention of confinement bypass through an annulus.

High-performance generation

The ATME1 reactor is designed for a thermal efficiency of 37 percent (leading to fuel economy and waste reduction), a 60-year service life, and an availability factor of more than 92 percent over the life of the plant (through fuel cycles of up to two years, and short refueling outages made possible by access to the reactor building during operation and in-service maintenance). The ATME1 reactor also provides load-follow and frequency control capabilities, which allow the reactor to be adapted to various grid requirements—at either 50 or 60 Hz—to provide utilities advanced operational flexibility.

Ready for construction

The IAEA completed a review of the ATME1 reactor's conceptual design safety features in 2008 and concluded that the design was compliant with the agency's fundamental safety principles and key design and safety assessment requirements. France's Autorité Sûreté Nucléaire (ASN) completed a review of the ATME1 reactor, commissioned by vendors AREVA and MHI, in January 2012. It concluded that ATME1's key safety options and general design choices satisfactorily met current French regulatory and quasi-regulatory measures, as well as the 2004 technical guidelines for the design and construction of new-generation PWRs. ASN also praised efforts to incorporate early lessons learned from the Fukushima Daiichi nuclear accident.

In June 2013, the Canadian Nuclear Safety Commission (CNSC) completed Phase 1—the Pre-Licensing Assessment of Compliance with CNSC Regulatory Requirements and Canadian Codes and Standards—of the pre-licensing vendor design review of the ATME1 reactor. It was determined that ATME1’s design intent meets the most recent CNSC regulatory design requirements and expectations for a new nuclear power plant in Canada.

With its potential for use in nuclear projects in other countries as well, the ATME1 reactor has great commercial prospects throughout the world.

For further information on the ATME1 reactor, please visit ATME1's website at <www.atmea-sas.com>.